

**Control system for hydraulic cylinder, plug with a hydraulic cylinder and methods for setting and releasing a plug**

5 The present invention regards a control system for a hydraulic cylinder, a plug with a hydraulic cylinder for closing off a pipeline and methods for setting and or releasing said plug in said pipeline.

10 Plugs in this context should be understood to be an element with anchoring and sealing devises, which element is conveyed in a pipeline to close or seal off the pipeline at a certain point in the pipeline. These plugs may be permanent or temporary, which in the latter case means that they are removable after they have  
15 performed their task. Removable plugs are more and more used when there is a need for closing off a pipeline, for instance when an oil/gas pipeline has to be repaired due to for instance corrosion, collapses or other damages. Plugs are also now more used instead of valves fitted in the pipeline during building of the pipeline. This because the plug is now flexible and also since there often are  
20 problems with closing a valve that has been sitting inactive in a pipe for several years. If the plug should compete with an ordinary valve is the need for a reliable plug a vital necessity.

Previously plugs have been used to close of a fluid stream at a certain point in a pipeline where the distance to an entry point for the plug has been of a limited  
25 length, which means the plug may have direct contact with the outside of the pipeline through for instance a cable. Now the pipelines are becoming longer and the need for using plugs further from an entry point is increasing. This means there are no possibility of having cable feed plugs, so the plugs must be remotely controlled or autonomous, with no feed lines to the outside of the pipeline. This is  
30 the case for instance for pipelines running from an offshore installation to an onshore processing plant or supply pipelines for gas and oil from a oil field to the user market.

When using a plug in a major pipeline from a gas/oil field to a user market or a processing plant there must be an absolute certainty that the plug operates according  
35 to plan both when setting the plug but especially when releasing the plug. The damage done if a plug isn't setting is large but not at all comparable with the damage done if one is not able to release an already set plug. That may cost several days, months or even years of unnecessary loss of production from an entire oil/gas field in addition to costs related to changing the part of the pipeline where the plug is stuck. So there is an absolute must to have the certainty that once the plug is set  
40 one is able to release it again.

The system must also be reliable over time since the case may be that the plug is set and sits there for several months or years and then should be released.

Another use for removable plugs are if valve elements need to be maintained, a new field should be added to a main pipeline or even in the case where a water pipe from for instance a water dam has to be mended or replaced. The plugs may be used in pipes with a pressurized fluid. If the plug is of a kind with no cable feed it may be use wherever in the length of the pipe.

Prior art plugs are of a kind having anchoring and sealing means operated by at least one hydraulic cylinder with a control system, with a control valve which is closed in a neutral position, i.e. the valve is only open when energy is feed to the valve. The plug is set by feeding energy to the valve so it goes to an open position, hydraulic fluid is pressurized through the valve to the hydraulic cylinder and the hydraulic cylinder is setting the anchoring and/or sealing means. When the plug is set, the energy is cut off to the valve and it closes, with the hydraulic cylinder in a pressurized position, with the anchoring and or sealing means in a set position.

For releasing the plug a signal and energy has to be feed to a valve in the plug to open the valve to relieve the pressurized hydraulic fluid in the hydraulic cylinder – to be able to retract the anchoring and sealing means. This is a critical procedure, and normally there is at least one backup system for this in the plug, in case the procedure does not work, either due to lack of available energy, damage to the control line, a stuck valve or other incidents. To get a necessary security in this system, when talking about a central pipeline from a large oilfield, there is as mentioned at least one and normally several backup system. These backup systems take vital room in the plug and make the plug more complicated - both in production and also in maintenance. Several elements and systems in the plug make the plug also less reliable.

It is an object of the present invention to provide a control system for a hydraulic cylinder which may be used in a plug, which may release the hydraulic cylinder without energy supply to elements in the plug. There is also an object to provide a plug which is easier to produce and maintain and at the same time gives the necessary security in the setting and releasing procedure. There is also an object to provide a plug and a method for setting and releasing the plug which plug and method do not need additional back-up systems for securing the release of the plug. To obtain a more reliable plug is also an object of the invention.

A control system for a hydraulic cylinder, a plug with a hydraulic cylinder and method for setting and releasing a plug wherein the above mentioned objects are achieved is obtained with a control system, plug and methods according to the independent claims. Further features of the invention appear from the dependent claims.

A control system according to the invention is used for a hydraulic cylinder. With the term hydraulic cylinder it is meant a cylinder with endplates and a piston head

within said cylinder and a piston rod running from said piston head and out of said chamber on one or both sides of the piston head. The control system for the hydraulic cylinder comprises a fluid line between at least on side of the hydraulic cylinder's piston head and a source of hydraulic fluid. This fluid line comprises in  
5 at least a part two parallel lines. In one of the lines is there arranged a pump. The other parallel line comprises a control element. This control element allows less fluid through the line in the opposite direction of the pump, than the pump when the pump is running.

The invention also regards a plug with anchoring and sealing devices operated by at  
10 least one hydraulic cylinder, which is operated by a control system for setting and/or releasing the plug. The hydraulic cylinder may operate both anchoring and sealing devices or just one of them or there may be several hydraulic cylinders for operation of for instance the anchoring system.

The plug according to the invention is used for closing of a pipeline for the stream  
15 of a fluid. The pipeline is normally a gas and or oil pipeline but may also be a pipeline or pipe or tube for any other fluid. The plug is preferably remotely operated, but can be operated by control lines running through the pipeline to an entry point.

The control system for the hydraulic cylinder comprises according to the invention,  
20 a fluid line between at least on side of the hydraulic cylinder's piston and a source of hydraulic fluid. Between these two points there is for at least a part of the line, two parallel lines where one of them comprises a pump and in the other line is there arranged a control element. This control element is of a kind that allows less fluid through this line in the opposite direction of the pump, than the pump when the  
25 pump is running.

The control element may be a restriction orifice or a valve, which valve according to the present invention in a neutral position is open.

This means that the valve have to be feed a signal and energy to be switched to a closed position, where after or at the same time the motor is turned on and thereby  
30 running the pump and hydraulic fluid is feed into the hydraulic cylinder to set the plug in the pipeline. By setting the plug it is meant using the anchoring means for positioning the plug in the pipeline and hold it there and thereafter or simultaneously pressing the sealing devises of the plug against the inner surface of the pipeline to prevent fluid moving from one side of the plug to the other side of  
35 the plug.

When the plug is set and there is a differential pressure across the plug the signal and energy to the valve and motor is turned off and the valve goes back to its neutral position; which is open. The hydraulic pressurized fluid in the hydraulic

cylinder is relieved and partly returns due to the open valve back to the hydraulic source. The hydraulic cylinder is therefore not exercising any pressure on the anchoring and or sealing devices and there is no need for a back-up system to be sure to be able to relieve the pressure in the hydraulic cylinders once the plug should be removed.

In the other embodiment where the control element is a restriction orifice, will the pump by its larger capacity for moving fluid through the line than the other parallel line, build pressure in the hydraulic cylinder when it is running. This even though there always will be some fluid that flows back through the restriction orifice. When the pump is turned off the pressure in the hydraulic cylinder will slowly decrease since the hydraulic fluid will return slowly through the restriction orifice. By this one achieves a depressurised hydraulic cylinder in the plug which is set in the pipeline, and there is a possibility to release the plug without energy supply to the plug. The plug may be released by again build pressure on the side of the plug which was relieved when the plug was set.

In a preferred embodiment of the plug it comprises a hydraulic cylinder with a through going piston rod and the source of hydraulic fluid is the void on the other side of the piston head. This solution also renders it possible to use a two-way pump in the system; however in the preferred embodiment it is used a one way pump. The fluid lines in the preferred embodiment runs from one sub-chamber to the other sub-chamber, one on each side of the piston head, of the cylinder chamber.

The hydraulic cylinder in the plug for operating the anchoring and or sealing devices are in the preferred embodiment preloaded to return to a neutral position where the anchoring means are in a retracted position. This preloading may be achieved by the sealing devises in it self, but another possibility is to arrange at least one spring between an endplate of the plug and an endplate of the hydraulic cylinder. A preloading of the hydraulic cylinder ensures that there is no need for a two-way operational pump, which would be an alternative, and one has a total passive system for releasing the plug. However, it is not an absolute necessity to have a preloaded hydraulic cylinder, it is possible to release the plug with pressure differences on the two sides of the plug.

The plug in the preferred embodiment comprises a first endplate and a second endplate. The hydraulic cylinder with a cylinder chamber is connected to the first endplate. The cylinder chamber comprises a piston head with a piston rod, which runs through said piston head and through the whole of said cylinder chamber, i.e. a double rodged cylinder. Sealing means in form of a packer is arranged in abutment to an inner side of said first endplate. A first part of said anchoring means in the form of a first wedge is situated behind said packer, a second part of said anchoring means is provided partly outside said first part of said anchoring means and in

abutment against a second endplate of said plug. The control system for the hydraulic cylinder comprises a valve with a neutral open position. Said second endplate is connected to the piston rod. Said piston rod extends preferably through both endplates.

- 5 This gives a plug which is compact and reliable, easy to maintain and may be set in a pipeline and left there for several months, even years before it is released again.

The present invention also regards a method for setting and releasing said plug. When setting the plug one inserts the plug in the pipe and moves it to the required position in the pipe. When the position is reached the setting procedure by closing  
10 said valve and starting said pump is activated. The pump then builds a necessary setting pressure in the hydraulic cylinder so that said anchoring means and or said sealing means is in close abutment with the internal wall of the pipeline and the plug is set and do not move. Then the pressure on one side of said plug is relieved until the pressure transmitters sense a sufficient differential pressure established  
15 across the plug and when this differential pressure is established the pump is stopped and the valve released to its neutral position, an open position.

When releasing the plug, the pump is inactive and the valve is in its neutral position which is open, one is building pressure on the non-pressure side of said plug and when said pressure reaches a set value the preloaded hydraulic cylinder will move  
20 the anchoring means to a retracted position and the plug is free. This is achieved without having to initiate a releasing procedure where valves have to be activated and feed energy to release the anchoring means. The procedure according to the invention is a totally passive system, which means it is a more reliable system.

One easy possibility to have a backup for this is to have a two-way pump in the  
25 circuit and activate the pump in a reverse direction at the same time as the valve is set to a closed position and by this the hydraulic cylinder is forcing the anchoring means to retract.

The plug according to the invention may be used instead of for instance a blind valve or any other stop valve in a pipeline in for instance a processing plant, it may  
30 be used for closing off a part of a oil and or gas line between one or several oilfields and a processing plant onshore and or a consumer market.

The invention will now be explained in detail with reference to the accompanying drawings where:

Fig. 1 shows a plug according to the invention in a pipeline with the anchoring  
35 means in the process of being set,

Fig. 2 shows the plug in fig. 1 in a set position, and

Fig. 3 shows a second embodiment of the control system according to the invention.

In fig 1 and 2 is shown a plug 2 according to the invention in a pipeline 1. The plug comprises anchoring devices 3 in form of wedges and sealing devices 4 in form of a packer. The plug has two endplates, 5 and 6 respectively, and a central hydraulic cylinder 8. The hydraulic cylinder 8 has a central axis mainly coinciding with the pipeline 1. The anchoring means 3 and sealing means 4 are situated around the circumference of the hydraulic cylinder 8 in the annulus between the hydraulic cylinder 8 and the pipeline 1, and between the two endplates 5 and 6. The second endplate 6 of the plug 2, also forms one of the hydraulic cylinders endplate 10, and the cylinder chamber 11 of the hydraulic cylinder formed by the cylinder 9 and the two endplates 10 are therefore connected to the second endplate 6 of the plug 2. The first endplate 5 of the plug 2 is connected to the hydraulic cylinders piston rod 13 whereto the piston head 12 is connected. The piston rod 13 runs in this preferred embodiment through the whole of the cylinder chamber 11, i.e. on both sides of the piston head 12. The hydraulic cylinder is preloaded to a neutral position of the plug where the anchoring means are in a retracted position, with a spring 15 between one endplate 10 of the hydraulic cylinder and the first endplate 5 of the plug 2.

The hydraulic cylinder has according to the invention a control system 14 for operating the hydraulic cylinder 8 and thereby the setting of the plug 2. The control system comprises a fluid line 20 for the hydraulic fluid from a first opening 18 in the cylinder chamber 11 on one side of the piston head 12 in the hydraulic cylinder 8 to a source of hydraulic fluid. In this preferred embodiment is the source the part of the cylinder chamber 11 on the other side of the piston head 12 where the fluid line ends in a second opening 19. This is possible since the piston rod 13 runs through the cylinder chamber 11 on both sides of said piston head 12. In the fluid line is there in a part with two parallel lines 20a, 20b, positioned a pump 22 with a motor 23 running the pump in the first line 20a. There are also a valve 21 with an open and a closed position, which valve is placed in parallel with said pump in the other parallel line 20b. There are also pressure transmitter 24 on both sides of the pump 22 and valve 21.

In fig. 1 is the plug in operation for being set in the pipeline. The valve 21 is activated an set in a closed position and the pump 22 is running and pumping hydraulic fluid through the first opening 18 in the cylinder chamber and increasing the pressure on this side of the piston head 12. The piston head 12 is by this moved in the cylinder chamber 11 and the two wedge parts of the anchoring means 3 are pushed on top of each other and setting the plug in the pipeline. The pump further pumps hydraulic fluid through the first opening 18, and the hydraulic cylinder 8 pulls the two endplates 5 and 6 of the plug together further and the sealing device 4 is clenched between the anchoring device 3 and the second endplate 6 and seals against the internal wall of the pipeline 1 as shown in fig. 2. The pressure in the

fluid in the pipeline is relieved on one side of the plug 2, and when a predetermined pressure difference between the two sides of the plug is noticed by the pressure transmitters then the pump is stopped and the valve is left in its neutral position, which is an open position. This situation of valve and pump is shown in fig. 1. The  
5 spring 15 is in this position pressed together and will help force the anchoring means to a retracted position when there is less pressure differences between the two sides of the plug again. The spring 15 is however not necessary.

Fig. 3 shows another embodiment of the control system according to the invention. The control system us regulation a hydraulic cylinder in a plug 2 in a pipeline 1,  
10 which hydraulic cylinder is operating the anchoring devises 3 and sealing devises 4 of the plug 2. The hydraulic cylinder has a through going piston rod 13, which runs through the whole cylinder chamber 11 wherein the piston head 12 is situated. . The hydraulic cylinder 8 is in this case also preloaded with a spring 15 situated between an endplate 5 of the plug and an endplate 10 of the cylinder chamber 11. The line  
15 in the control system runs from a first opening 18 in one of the sub-chamber of the cylinder chamber 11 to a second opening 19 in the other sub-chamber of the cylinder chamber 11. In a part of the line 20 is there arranged two parallel lines 20a and 20b. In the first of these lines 20a is there arranged a pump 22 with a motor 23, in the other line 20b is there arranged a restriction orifice 25. This restriction orifice  
20 25 has a maximum through flow which is much smaller than the capacity of the pump 22 when the pump 22 is running. By this one achieves that when the pump 22 is running a pressure is built in the hydraulic cylinder 8 on one side of the piston head 8, even though there is some return flow of fluid through the restriction orifice 25. When the pump 22 is turned off the level of pressure in the hydraulic cylinder 8  
25 on the pressurized side of the piston head 12 will slowly decrease until there is equal pressure between the "pressurized side" of hydraulic cylinder and the source of hydraulic fluid, since the fluid slowly will flow back through the restriction orifice 25. The source of hydraulic fluid, in the case shown in fig. 3, is on the other side of the piston head 8.

30 The invention has now been explained with a preferred embodiment, but the skilled person will be able to do modifications and alterations within the scope of the invention as defined in the claims. For instance may there be several hydraulic cylinders operating the plug and there may be one or several control systems for operating these. The control system for the hydraulic cylinder may be fully or partly  
35 situated within the hydraulic cylinder itself. There may be several packers for establishing a double barrier etc.